Selecting Dam Breach Inundation Software

Observations from Kentucky

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BACKGROUND

FEMA Hazard Mitigation Grant

Rapid Inundation Mapping
– 180 models using Geo-Dam-BREACH

Enhanced Inundation Mapping
– 7 models using HEC-RAS 1D
– 2 models using FLO-2D

Questionable Inundation Results:
– Low Head dams
– Dams in areas of flat topography
– Dams that are small in size
STUDY PURPOSE

- FEMA’s development of GeoDamBreach
- Questions about models and their intended use
  - Which models should be used in what situations?
- Pilot study
  - Compare several software packages
    - DAMBRK (1-D)
    - FLO-2D (2-D)
    - GeoDamBreach (1-D)
    - DSS-WISE (2-D)
    - HEC-RAS (1-D/2-D, unsteady-state)
    - HAZUS-MH
- Inform dam safety community about model selection
  - Decision was to focus on qualitative approach
STUDY APPROACH

Methods, Assumptions, and Data
STUDY APPROACH – METHODS AND ASSUMPTIONS

– Comparing model simulations:
  • Used previously completed dam breach studies by KDOW
  • Used existing models
  • Created new simulations

– Used breach hydrographs from existing studies
  • Where necessary, used existing studies’ breach parameters

– Dam breach inundation zones delineated using best available elevation data

– HAZUS-MH runs compared using output from all models at a single dam site

– Questionnaire → Lessons Learned/Best Practices
## STUDY APPROACH – DATA

### 14 Dam Breach Studies:

**Dam heights: 8 – 77 ft**  
**Normal Pool volumes: 0 (dry) – 7,944 acre-ft**

<table>
<thead>
<tr>
<th>Dam Name (NID-KY#)</th>
<th>Height (ft)</th>
<th>Normal Pool Vol. (acre-ft)</th>
<th>Boss-DAMBRK</th>
<th>DSS-WISE Lite</th>
<th>SMPDBK/GeoDB</th>
<th>HEC-RAS 1D</th>
<th>HEC-RAS 2D</th>
<th>FLO-2D</th>
<th>HAZUS</th>
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<tr>
<td>Beech Creek (0043)</td>
<td>67</td>
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<td>7944</td>
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<td>Scenic (0012)</td>
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BOSS-DAMBRK

- User interface by Boss International (now part of Autodesk)
- Engine is DAMBRK from NWS
- Has since been replaced by FLDWAV
- One dimensional, unsteady-state model
- DOS-BASED

- Input
  - Typical breach parameters or hydrograph
  - Cross section data
  - Bridge/culvert geometry or rating curves

- Output
  - High water profiles
  - Flood arrival times
  - Hydrographs at selected locations
DSS-WISE

- DSS-WISE = “The Decision Support System for Water Infrastructural Security”
- Funded by DHS, developed by the NCCHE at Ole Miss
- Web-based platform, DSS-WISE operates within DSAT (Dams Sector Analysis Tool) Viewer
- Uses 2-d computational engine (CCHE2D-FLOOD)
- Input:
  - ID from National Inventory of Dams
  - Typical breach parameters (for partial breach scenario)
  - Automatically utilizes NED, NBI, NID, & NLCD
- Output:
  - Inundation area
  - Arrival time shapefile
  - Max Depth shapefile
  - Summary report
HEC-RAS 1D

- RAS = “River Analysis System”, Developed by the Hydrologic Engineering Center of the US Army Corps of Engineers
- One-dimensional
- Can be run as a steady-state or unsteady-state simulation
- Input:
  - Cross section geometry, reach lengths, Mannings n
  - Discharge: peak flow (steady-state), hydrograph (unsteady-state)
  - Breach parameters or breach hydrograph
- Output:
  - Water surface elevation, average velocity, and other variables for each cross section
  - Depth grids, velocity grids using RAS-MAPPER
HEC-RAS 2D

- Combined 1D/2D
  - Channel can be modeled with cross sections in 1D
  - 2D overbank area is connected to channel through a lateral structure (“levee”-like) feature
- 2D only modeling available (no bridges)
- Allows for structured and unstructured meshes (triangles, squares, up to 8-sided cells)
- Inputs
  - Typical HEC-RAS setup, plus elevation data to define 2D area
- Outputs
  - Typical HEC-RAS output (1D)
  - Gridded Depths, WSELs, Velocities at max and at time-steps
FLO-2D

- Produced by FLO-2D Software, Inc.
- Simulates channel flow, unconfined overland flow, and street flow using a 2D engine
  - Cross sections can be imported from HEC-RAS for combined 1D/2D
- Models 2D flow using square grid elements
- Inputs:
  - Typical breach parameters, physical breach parameters (NWS-BREACH) or imported hydrograph
  - Elevation dataset
  - Roughness parameters
- Outputs:
  - Grid and/or shaded contour plots of depth, velocity, impact force
  - Animation of data
  - Numerous plots, tables that can be constructed for individual cells
  - Volume monitoring
Maximum depth contours

Maximum depth shaded contour plot
QUESTIONNAIRE

What’s the right tool for the job?

– Return on Investment/Up Front Costs
  • License fees
  • Training and learning curve
  • Supporting software fees
    o GIS

– Breach Hydrograph
  • Sunny Day and Overtopping events?

– Output data
  • Does it fit project needs
  • Validation and Diagnostics

– Agency requirements and preferences
  • Do you (or FEMA) have existing models on hand?
  • Reusable, Recyclable?

– Long term support of software
RESULTS

Breach inundation areas, Profiles, Costs, etc.
BEECH CREEK DAM – AN EXAMPLE

– Approximately 70’ tall earth dam
– Tributary valleys just DS of dam
  • Is 2-D necessary?
– Modeled in:
  • GeoDamBREACH
  • HEC-RAS (1D & 2D)
  • DAMBRK
  • FLO-2D
  • DSS-WISE
– HAZUS Runs using all models’ output
  • Economic losses
BEECH CREEK – BREACH INUNDATION AREAS

COMPARISON:
HEC-RAS 1D, HEC-RAS 2D, & DSS-WISE
Lessons Learned

– EAP analysis level software Lessons Learned
  • DSS-WISE Lite can be used as a first pass to determine study extents to inform an more detailed analysis in HEC-RAS or FLO-2D for instance
  • DSS-WISE Lite and GeoDam-BREACH model setup times < 1 hour
  • GeoDam-BREACH creates flood risk products overlapping with floodplain mapping goals

– Detailed Software Lessons Learned
  • FLO-2D capable of integrating with SWMM but requires annual subscription
  • HEC-RAS 2D free, quick model setup (in 2D only), capable of leveraging existing models
  • FLO-2D Basic and HEC-RAS are FEMA approved
  • HEC-RAS 1D is only software capable of modeling bridges
Lessons Learned

- Aligning with FEMA Floodplain mapping program
  - Dual use funding to stretch dollars
  - Leveraging existing FEMA models

- Model Diagnostics
  - DSS-WISE Lite – black box

- Developer Support
  - BOSS DMBRK no longer supported by developer
  - FLO-2D
  - HEC-RAS
  - DSS WISE Lite
  - GeoDam-BREACH

- HAZUS-MH
  - Accepts ESRI Grid data of WSELs
Wrapping Up

– All models are valuable in the right situation

– The key is to understand your situation
  • What are types and resolution of your inputs and required outputs

– Get additional details about each model from FEMA P-946
QUESTIONS?

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